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Flammability Properties of "Frianyl A 63 RV0 Grey" - Report Summary

A Report To: **Phoenix Contact GmbH & Co. KG**
Flachsmarkstrasse 8
D-32825 Blomberg
Germany

Submitted By: Fire, Flammability & Explosivity

Report No. 04-02-305
10 pages + 1 appendix

Date: April 7, 2004

ACCREDITATION Standards Council of Canada, Registration #1.

REGISTRATION ISO 9002-1994, registered by QMI, Registration #001109.

SPECIFICATIONS OF ORDER

Determine surface flammability in accordance with ASTM E 162, rate of smoke generation according to ASTM E 662, toxic gas production according to Bombardier SMP 800-C and effective heat of combustion according to ASTM E 1354, as per our Quotation No. 0000195 accepted April 6, 2004.

Note: This report is a compilation of test report data acquired for the same material, but submitted for testing on different occasions. Reference original test report numbers include 03-02-494, 03-02-552 and 04-02-041.

IDENTIFICATION

Plastic material, approximately 4.2 - 4.4 mm in thickness, identified as "Frianyl A 63 RV0 Grey".

(BMTC sample identification numbers 03-02-S0494, 03-02-552 & 04-02-S0041)

SUMMARY

Material	Test	Report No.	Pass	Fail
Frianyl A63 RV0 Grey	ASTM E 162	03-02-552	Pass	-
Frianyl A63 RV0 Grey	ASTM E 662	03-02-494	Pass	-
Frianyl A63 RV0 Grey	SMP 800-C	03-02-494	Pass	-
Frianyl A63 RV0 Grey	ASTM E 1354	04-02-041	No criteria	No criteria

TEST RESULTS ASTM E 162-02a

Report 03-02-552

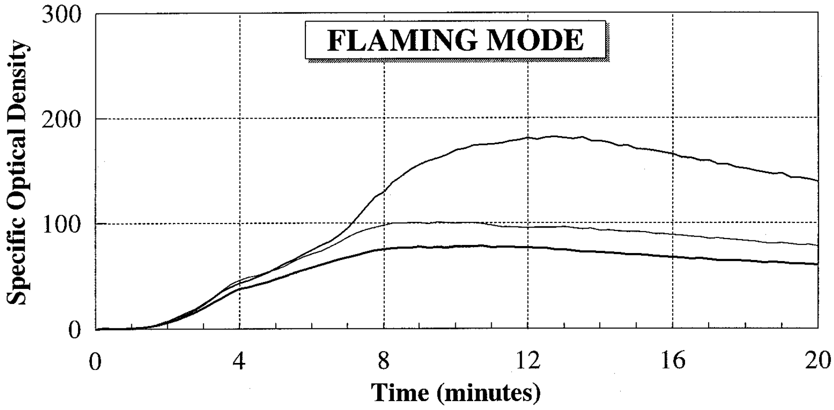
Surface Flammability of Materials Using a Radiant Heat Energy Source. (Is = Flame Spread Index).

	Fs	Q	Is	Observations
1:	1.0	4.9	5	Maximum flame front propagation distance of 5 inches.
2:	1.3	5.9	7	Dripping observed but the drips were not flaming.
3:	1.3	4.7	6	
4:	1.0	3.1	3	
Rounded Average:			5	
Specified Maximum:			35	No Flaming Running or Flaming Dripping Allowed

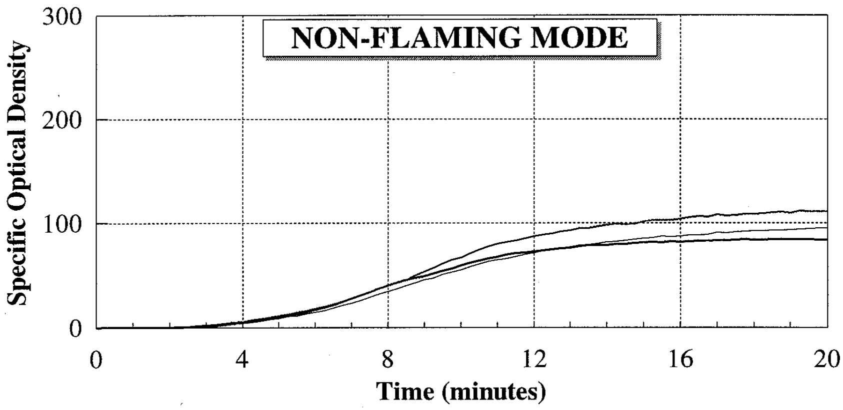
TEST RESULTS (Cont..) **ASTM E 662-03**

Specific Optical Density of Smoke Generated by Solid Materials

Report 03-02-494



Flaming Mode	Test	#1	#2	#3	Average	Specified Maxima
Specific Optical Density at 1.5 minutes		3	2	2	2	100
Specific Optical Density at 4.0 minutes		38	44	46	42	200
Maximum Specific Optical Density		78	182	100	120	-
Maximum Corrected Optical Density		71	169	92	111	-



Non-Flaming Mode	Test	#1	#2	#3	Average	Specified Maxima
Specific Optical Density at 1.5 minutes		1	1	1	1	100
Specific Optical Density at 4.0 minutes		6	5	4	5	200
Maximum Specific Optical Density		85	112	95	97	-
Maximum Corrected Optical Density		81	108	92	94	-

TEST RESULTS (Cont..)

Report 03-02-494

Bombardier SMP 800-C

Toxic Gas Generation

		Flaming Mode	Non-Flaming Mode	Specified Maxima
Carbon Monoxide (CO ppm)				
	at 1.5 minutes	<10	<10	-
	at 4.0 minutes	85	<10	-
	at maximum	448	<10	3500
Carbon Dioxide (CO2 ppm)				
	at 1.5 minutes	<50	<50	-
	at 4.0 minutes	2300	<50	-
	at maximum	24850	<50	90000
Nitrogen Oxides (as NO2 ppm)		11	2	100
Sulfur Dioxide (SO2 ppm)		<1	<1	100
Hydrogen Chloride (HCl ppm)		3	<1	500
Hydrogen Fluoride (HF ppm)		<2	<2	100
Hydrogen Bromide (HBr ppm)		<1	<1	100
Hydrogen Cyanide (HCN ppm)		64	3	100
Original Weight (g)		27.0	27.0	-
Final Weight (g)		Not determinable	Not determinable	-
Weight Loss (g)		-	-	-
Weight Loss (%)		-	-	-
Time to Ignition (s)		21	Did not ignite	-
Burning Duration (s)		850	-	-

TEST RESULTS (Cont..)

ASTM E 1354-03

Heat and Visible Smoke Release Rates for Materials and Products
Using an Oxygen Consumption Calorimeter

Report 04-02-041

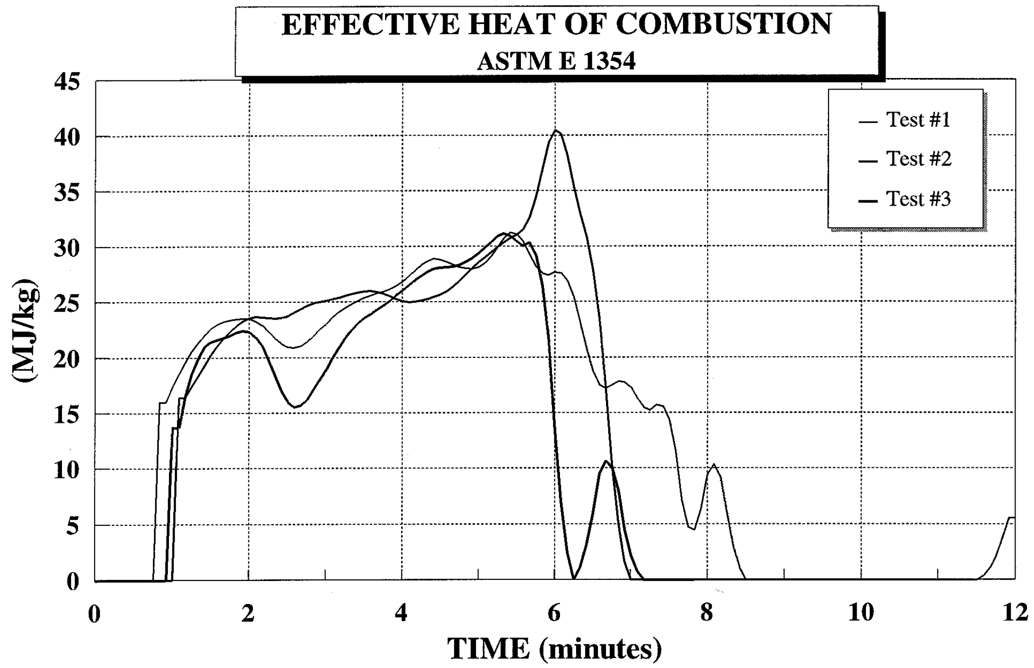
Heat Flux: 50 kW/m² — Exhaust Flow Rate: 24.0 l/s

Testing was performed in the horizontal configuration and using the specimen holder edge frame.

	Test #1	Test #2	Test #3	Average	
Specimen Thickness (mm)	4.3	4.3	4.4		
Initial Mass (g)	51.0	52.7	52.6		
Final Mass (g)	2.3	3.3	3.2		
Total Mass Loss (kg/m²)	4.87	4.93	4.95	4.92	
Peak Mass Loss Rate (g/s·m²)	29.91	27.39	27.76	28.35	
Average Mass Loss Rate (g/s·m²)	20.07	20.88	22.46	21.14	
Time to Ignition (s)	46	63	56	55	
Time to Flame-out (s)	720	533	471	575	
Time of Peak Rate of Heat Release (s)	220	245	240	235	
Peak Rate of Heat Release (kW/m²)	791.9	682.3	736.7	737.0	
Average Rate of Heat Release (kW/m²)	172.6	263.2	268.5	234.8	
Total Heat Released (MJ/m²)	116.47	123.70	111.41	117.19	
Average Effective Heat of Combustion (MJ/kg)	23.90	25.07	22.53	**23.83**	*
Average Effective Heat of Combustion (BTU/lb)	10293	10798	9702	**10264**	*
Caloric Content (MJ/kg)	22.83	23.48	21.16	**22.49**	**
Caloric Content (BTU/lb)	9833	10113	9114	**9687**	**
Peak Extinction Area (m²/kg)	376.8	391.2	550.0	439.3	
Average Extinction Area (m²/kg)	117.1	134.4	124.9	125.5	

* Total heat produced per unit mass of material consumed
** Total heat produced per unit mass of material tested

TEST RESULTS (Cont..)

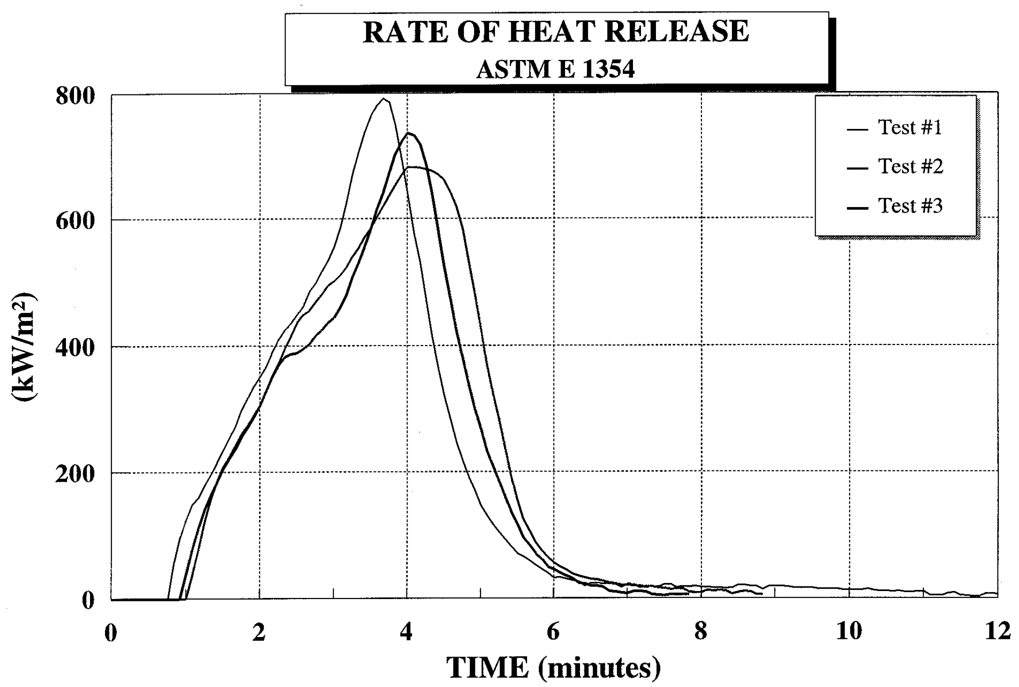


	Test #1	Test #2	Test #3	Average
Average Heat of Combustion (MJ/kg)*	23.90	25.07	22.53	23.83
Heat of Combustion @ 60 s (MJ/kg)**	20.38	20.53	20.17	20.36
Heat of Combustion @ 180 s (MJ/kg)**	22.73	23.84	20.20	22.26
Heat of Combustion @ 300 s (MJ/kg)**	24.44	25.30	22.87	24.20

* Averaged over the period starting when 10% of the ultimate mass loss occurred and ending at the time when 90% of the ultimate mass loss occurred.

** Averages over the 60, 180 or 300 second periods starting when 10% of the ultimate mass loss occurred.

TEST RESULTS (Cont..)

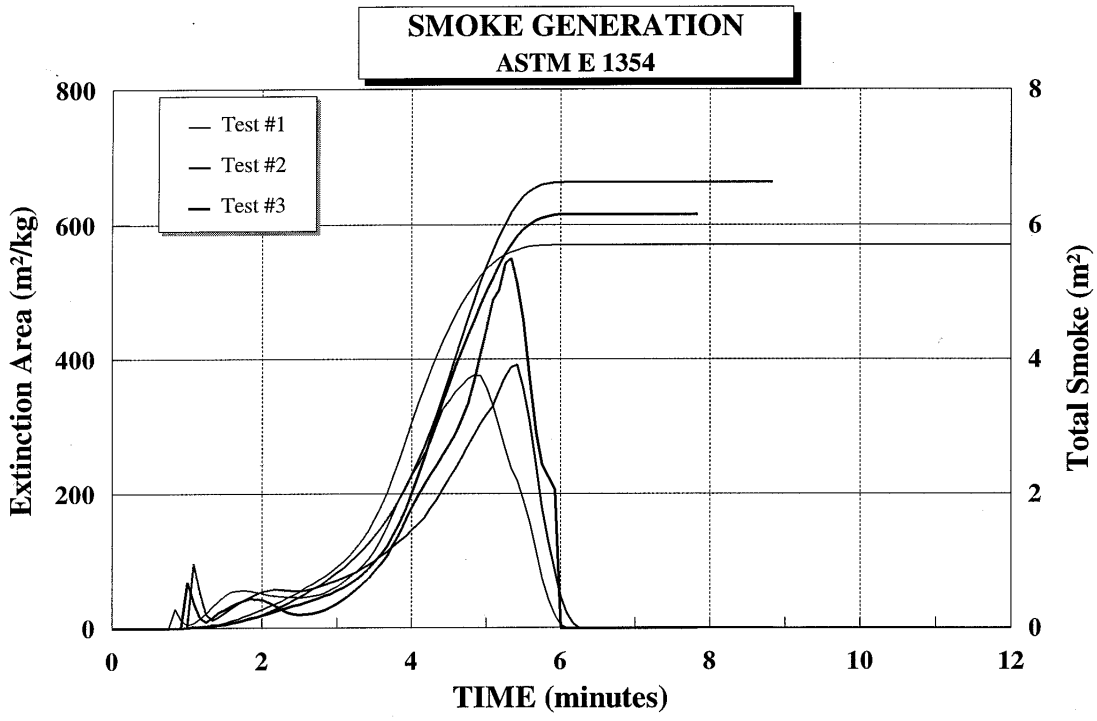


	Test #1	Test #2	Test #3	Average
Peak Rate of Heat Release (kW/m^2)	791.9	682.3	736.7	737.0
Average Heat Release Rate (kW/m^2)*	172.6	263.2	268.5	234.8
Heat Release Rate @ 60 s (kW/m^2)**	197.4	210.7	194.4	200.8
Heat Release Rate @ 180 s (kW/m^2)**	432.5	416.4	390.6	413.2
Heat Release Rate @ 300 s (kW/m^2)**	367.0	401.6	365.1	377.9

* Averaged over the test period (from ignition to flameout).

** Averages over the first 60, 180 or 300 seconds after ignition.

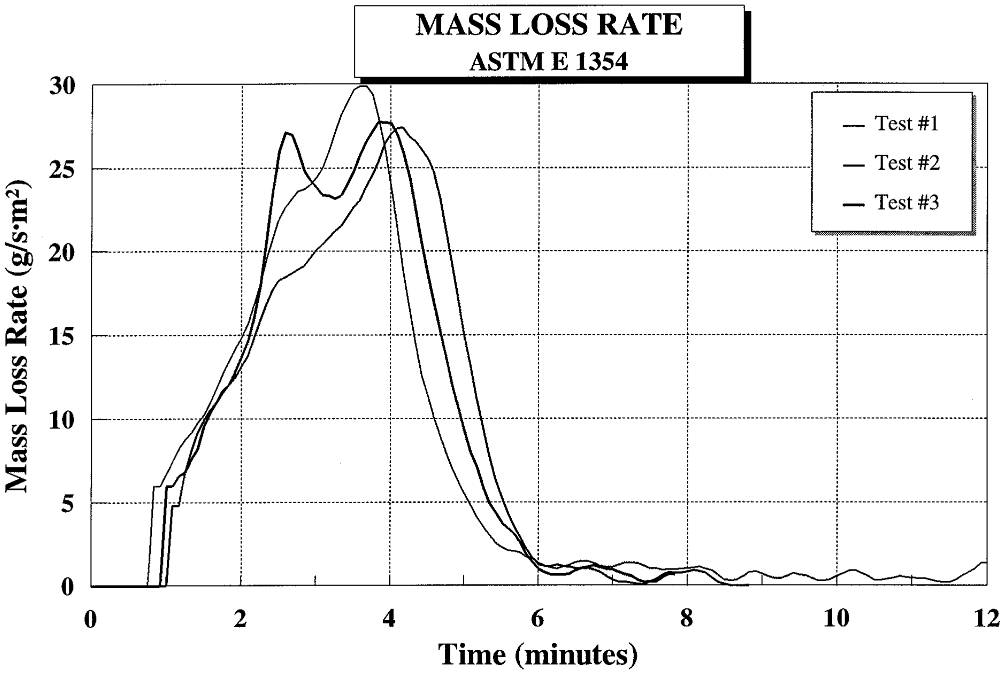
TEST RESULTS (Cont..)



	Test #1	Test #2	Test #3	Average
Peak Extinction Area (m^2/kg)	376.8	391.2	550.0	439.3
Average Extinction Area (m^2/kg)*	117.1	134.4	124.9	125.5
Extinction Area @ 60 s (m^2/kg)**	33.4	36.0	32.5	34.0
Extinction Area @ 180 s (m^2/kg)**	69.7	75.6	54.5	66.6
Extinction Area @ 300 s (m^2/kg)**	126.6	139.1	128.5	131.4
Total Smoke (m^2)	5.7	6.6	6.2	6.2

* Averaged over the test period (from ignition to flameout).
** Averages over the first 60, 180 or 300 seconds after ignition.

TEST RESULTS (Cont..)



	Test #1	Test #2	Test #3	Average
Peak Mass Loss Rate (g/s·m²)	29.91	27.39	27.76	28.35
Average Mass Loss Rate (g/s·m²)*	20.07	20.88	22.46	21.14
Mass Loss Rate @ 60 s (g/s·m²)**	9.68	10.26	9.64	9.86
Mass Loss Rate @ 180 s (g/s·m²)**	19.03	17.47	19.34	18.61
Mass Loss Rate @ 300 s (g/s·m²)**	15.02	15.87	15.97	15.62

* Averaged over the period starting when 10% of the ultimate mass loss occurred and ending at the time when 90% of the ultimate mass loss occurred.

** Averages over the 60, 180 or 300 second periods starting when 10% of the ultimate mass loss occurred.

CONCLUSIONS

The polyamide material identified in this report, when tested at an approximate thickness of 4.2 to 4.4 mm, meets The Federal Railroad Administration requirements as they pertain to surface flammability (ASTM E 162) and rate of smoke generation (ASTM E 662).

The polyamide meets Bombardier requirements as they pertain to toxic gas production (Bombardier SMP 800-C).

The polyamide affords an average Effective Heat of Combustion of 23.83 MJ/kg (10264 BTU/lb) of consumed material when tested according to ASTM E 1354 at an imposed heat flux of 50 kW/m². Based on the initial mass of each specimen, this calculates to an overall average Caloric Content of 22.49 MJ/kg (9687 BTU/lb).

I. Smith,
Fire, Flammability & Explosivity.

Richard J. Lederle,
Fire, Flammability & Explosivity.

Note: This report consists of 10 pages, including the cover page, that comprise the report "body". It should be considered incomplete if all pages are not present. Additionally, the Appendix of this report comprises a cover page, plus 5 pages.

APPENDIX
(5 Pages)

Summaries of Test Procedures
ASTM E 1354 Definitions

Bodycote Materials Testing Canada Inc.

ASTM E 162-02a

Surface Flammability of Materials Using a Radiant Energy Source.

Four specimens, 6 x 18 inches in size, are pre-dried for 24 hours at 60°C and conditioned to equilibrium at 50 ± 5% relative humidity and 23 ± 3°C before testing.

Each specimen is mounted into a holder and inclined at 30° from the vertical in front of a 12 x 18 inch gas-fired radiant panel. The orientation of the specimen is such that ignition is forced near its upper edge by a pilot flame, and the flame front progresses downwards.

A factor derived from the rate of progress of the flame-front and the rate of heat liberation by the material under test is calculated as follows and then reported after rounding to the average of the tests to the nearest multiple of 5:

$$Is = Fs \cdot Q$$

Where: Is is the flame spread index

Fs is the flame spread factor

Q is the heat evolution factor

Transit authorities generally specify a maximum Is acceptance criterion of 35 for general applications, and 100 for light diffusers, windows and transparent plastic windscreens.

Bodycote Materials Testing Canada Inc.

ASTM E 662-03

Specific Optical Density of Smoke Generated by Solid Materials (NBS Smoke Chamber)

This method of test covers a procedure for measuring the smoke generated by solid materials and assemblies in thickness up to and including 1 inch (25.4 mm). Measurement is made of the attenuation of a light beam by smoke (suspended solid or liquid particles) accumulating within a closed chamber due to nonflaming pyrolytic decomposition and flaming combustion. Results are expressed in terms of specific optical density (Ds), which is derived from a geometrical factor and the measured optical density (absorbance).

Specimens are dried for 24 hours at 60°C and conditioned to equilibrium at 50% RH and 23°C.

Three specimens, 3" square, are exposed to each mode of combustion. The % light transmittance during the course of the combustion is recorded. These data are used to express the quantity of smoke in the form of Specific Optical Density based on the following formula which assumes the applicability of Bouguer's law:

$$Ds = (V/AL)\cdot\log(100/T) = G\cdot\log(100/T) = 132\cdot\log(100/T)$$

Where: Ds = Specific Optical Density
T = % Transmittance
V = Chamber Volume (18 ft^3)
A = Exposed Area of the Sample (0.0456 ft^2)
L = Length of Light Path in Chamber (3.0 ft)
G = Geometric Factor

Among the parameters normally reported are:

$Ds_{1.5}$	- specific optical density after 1.5 minutes
$Ds_{4.0}$	- specific optical density after 4.0 minutes
Dm	- maximum specific optical density at any time during the 20 minute test
$Dm_{(corr)}$	- Dm corrected for incidental deposits on the optical surfaces

Transit authorities generally specify a maximum Ds 1.5 of 100 and a maximum Ds 4.0 of 200 in either flaming or non-flaming test mode.

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Bombardier SMP 800-C

Toxic Gas Sampling and Analytical Procedures

Toxic Gas Generation
Gases produced for analysis are generated in a specified, calibrated smoke chamber during standard rate of smoke generation testing (typically ASTM E 662), in both flaming combustion and non-flaming pyrolytic decomposition test modes.

Carbon Monoxide (CO) and Carbon Dioxide (CO2)
CO and CO2 are monitored continuously during the 20 minute test using a non-dispersive infrared (NDIR) analyzer. Data are reported in ppm by volume at 1.5 and 4.0 minutes and at maximum concentration.

Acid Gas Sampling
HCN, HF, HCl, HBr, NOx and SO2 are sampled by drawing 6 litres of the chamber atmosphere through two midget impingers, each containing 10 ml of 0.25N NaOH, at a rate of 400 ml per minute. The 15 minute sampling period is commenced at the 4 minute mark. All determinations are performed in both the flaming and non-flaming modes and all data are reported in parts per million (ppm) by volume in air.

Analysis of Impingers for Hydrogen Cyanide (HCN)
Cyanide in the NaOH impinger, as NaCN, is converted to CNCl by reaction with chloramine-T at pH greater than 8 without hydrolyzing to CNO^-. After the reaction is complete, CNCl forms a red-blue colour on addition of a pyridine-barbituric acid reagent. Cyanide is quantified by spectrometric measurement of the increase in colour 578 nm. Reference: In-house SOP 00-13-SP-1216 based on ASTM Method D 2036-91

Analysis of Impingers for Hydrogen Fluoride (HF)
Fluoride, as NaF, in the NaOH impinger is determined using SPADNS colorimetry.
Reference: In-house SOP 01-13-SP-1295

Analysis of Impingers for Hydrogen Chloride (HCl) and Hydrogen Bromide (HBr)
Alkali halides (chloride and bromide) formed in the NaOH solution are measured using ion chromatography and conductivity detection. Reference: In-house SOP 93-T34-SP-007

Analysis of Impingers for Nitrogen Oxides (NOX)
Nitrite and nitrate formed in the alkaline solution are determined using ion chromatography and conductivity detection. The nitrite and nitrite results are combined and the total expressed as nitrogen dioxide (NO2).
Reference: In-house SOP 93-T34-SP-007

Analysis of Impingers for Sulfur Dioxide (SO2)
SO2 is trapped in the NaOH impinger as sulfite and sulfate ($SO3^{-2}$ and $SO4^{-2}$). Hydrogen peroxide is added to convert $SO3^{-2}$ to $SO4^{-2}$. Resulting sulfate is determined using ion chromatography and conductivity detection. Reference: In-house SOP 93-T34-SP-007

Bodycote Materials Testing Canada Inc.

ASTM E 1354-03

Heat and Visible Smoke Release Rates for Materials and Products
Using an Oxygen Consumption Calorimeter

Three specimens, 100 mm x 100 mm in size, are conditioned to equilibrium at 50 ± 5% relative humidity and 23 ± 3°C before testing.

Each specimen is mounted into a holder and placed horizontally below a cone-shaped radiant heat source which has been previously set to emit a specified heat flux. A spark source is located 13 mm above the surface of the specimen in order to promote ignition in ambient air conditions, while a load cell continuously monitors specimen weight loss.

Exhaust gas flow rate and oxygen concentration are used to determine the amount of heat release, based on the observation that the net heat of combustion is directly related to the amount of oxygen required for combustion. The relationship is that approximately 13,100 kJ of heat are released per 1 kg of oxygen consumed.

In addition to rate of heat release, other measurements include mass-loss rate, time to sustained flaming and smoke obscuration.

Bodycote Materials Testing Canada Inc.

ASTM E 1354-03 DEFINITIONS

In evaluating the data produced by the oxygen consumption (cone) calorimeter, the following definitions and comments are offered:

Effective Heat of Combustion	This is the measured heat release divided by the mass loss for a specified time period and represents, therefore, the calorific value of the consumed portion only of the tested material. Caloric content under the test conditions can be derived by dividing the total heat released by the original mass of the material under test. It generally differs from the theoretical heat of combustion, since the latter involves complete combustion - a phenomenon which rarely takes place in an actual fire.
Time to Ignition	Also known as ignition delay time, this parameter provides a measure of a material's propensity to ignition as measured by the time to sustained ignition at a given heat flux. It can also be considered to be related to the volatility of the degradation products and the time required to achieve a critical fuel concentration in the vapour phase. This gasification rate is temperature dependent: the higher the imposed heat flux the shorter the time to ignition.
Heat Release Rate (HRR)	HRR is the heat evolved per unit time and is highly dependent on applied heat flux: the higher the flux the greater the HRR. HRR curves can fluctuate significantly with time and it is generally considered that the average HRR can be a better predictor of full-scale fire performance than the peak value.
Total Heat Release	This is the integrated area under the HRR curve over the test period, expressed in MJ/m^3. If one knows the surface area of a material used in a room or transit vehicle, this value is more properly used to estimate "potential heat load" than is the more commonly used "caloric content" based upon the weight of material used.
Mass Loss Rate	This is roughly correlatable with heat release rate because it is the rate at which the test material is degraded to produce combustible fuels. The peak mass loss rate and average mass loss rate are derivative terms generated by the load cell.
Extinction Area	This refers to the "yield" of smoke which is, through mathematical manipulation, expressed as an area per unit mass.

In addition to average values for the test, data averaged to the 60, 180 and 300 second marks after ignition are also typically provided. Where materials burn for different lengths of time, for example, it is more technically sound to compare the average heat release rates over the first 1, 3 or 5 minutes of burning than to compare the test average results which encompass differing time periods.